

Development and characterization of composites reinforced with textile waste

Abstract

The ever-increasing population and, most importantly, 'fast fashion' has put the demand for clothing high. The increased consumption of textiles led to increased waste. The textile waste, if not appropriately managed it can cause serious health hazards. The conventional methods of textile waste management, such as landfilling and burning, are not environmentally friendly. Therefore, it is necessary to develop new ways to recycle or reuse waste textiles and find new applications.

In this research, in the first section, thermoset epoxy and thermoplastic polypropylene (PP) composites with four different fibre volume fractions (0.1, 0.2, 0.3, and 0.4) were developed using cotton fibres extracted from waste textiles and waste polyester fibres generated during polyester staple yarn manufacturing. The fibres extracted from waste textiles are called shoddy. The cotton shoddy and polyester fibres were processed on carding machines to produce oriented fibre web. This oriented fibre web was used as a preform. The thermoset resin mixed with the curing agent was applied uniformly on the fibre web. The thermoset composites were developed using a compression molding machine. The mechanical performance in terms of tensile, flexural, and impact properties of cotton and polyester fibre epoxy composites with 0.3 fibre volume fraction was found better. The average tensile, impact, and pinned joint strength of polyester/epoxy composites was higher than cotton/epoxy composites. However, the average flexural strength of cotton/epoxy composites was found higher than polyester/epoxy composites. The water absorption causes a notable change in the mechanical properties of these composites. Further, the tensile strength of cotton/PP composites decreases with an increase in fibre loading. In contrast, the izod impact strength increases with an increase in cotton fibre loading. The flexural strength of cotton/PP composite increases with an increase in cotton

loading from 20 to 40wt% and decreases when cotton loading increases to 50wt%. The tensile, flexural, and izod impact strength of polyester/PP composites increases with polyester fibre loading.

An effort has been made to enhance the mechanical properties of the cotton/epoxy composites by incorporating reduced graphene oxide (rGO) nanoparticles in four different weight percentages (0.1, 0.3, 0.5, and 1wt%) and enzyme-treated hemp fibre (HF) microparticles in four different weight percentages (1, 2, 3, and 5wt%). The compression molding technique was used to produce the composite specimens. It has been found that the mechanical properties of composites loaded with 0.3wt% of rGO and 3wt% of HF microparticles show enhancement in mechanical properties, namely, tensile, flexural, izod impact, and pinned joint strength. The dynamic mechanical properties of the composites improve upon rGO and HF particles loading. However, the water absorption properties are not influenced by rGO and HF particle filler loading.

The yarn produced using fibres extracted from waste textiles were used to produce the 2D fabric, 3D homogeneous, and 3D hybrid orthogonal woven preforms. The 3D hybrid preform consists of glass yarn as a stuffer and wastes cotton yarn as a binder and filler. The four-layer 2D laminate and 3D composite specimens were developed using the vacuum-assisted resin infusion technique. The tensile and flexural properties composites were in order of 3D hybrid > 2D laminate > 3D homogeneous. In comparison, the impact strength was in the order of 3D hybrid > 3D homogeneous > 2D laminate.

The mechanical properties of textile waste-based composites can be improved by engineering the preform structure. Nine different types of preforms, namely, carded cotton web (SH), cotton nonwoven laminate (Nw), stitched cotton nonwoven laminate (NwSt), cotton web sandwiched between woven fabrics (Wb), cotton web sandwiched between woven fabrics, and stitched

(WbSt), nonwoven sandwiched between woven fabrics (Wn), nonwoven sandwiched between woven fabrics and stitched (WnSt), cotton web sandwiched between waste cotton yarn UD preform (WbUD), cotton web sandwiched between hybrid woven fabrics (WbH) were developed. These preforms were then converted to composites having ~0.3 fibre volume fraction using the compression molding technique. The composite specimen WbH exhibited a notable improvement of mechanical properties, namely, tensile, flexural, impact, and pinned joint strength, than all other composite specimens, followed by composite specimen WbUD. The mechanical properties of composite specimens Wb, WbSt, Wn, WnSt were approximately the same. The tensile and flexural properties of composite specimens Nw, NwSt, Wb, WbSt, Wn, WnSt are lower than SH. However, izod impact strength of SH was lower than composite specimens Nw, NwSt, Wb, WbSt, Wn, WnSt. The equilibrium water content of composite specimen Wb was substantially lower than SH.

In the last section, hybrid composites of carded cotton web laminated with unidirectional (UD) glass preform (in four weight percentages, namely, 7.64, 14.83, 21.59, and 27.96%) and jute nonwoven (in four weight percentages, namely, 3.59, 7.17, 10.76, and 14.34%) were developed. The tensile, flexural, impact, and pinned joint strength of hybrid composite specimens increases with UD glass preform loading. However, tensile and flexural properties of hybrid composites increased with an increase in jute nonwoven loading from 3.59 to 7.2wt%, and jute nonwoven loading beyond 7.2wt% does not help to improve these properties. However, the izod impact strength of the hybrid composites increased with an increase in jute nonwoven loading. The equilibrium water content decreases with UD glass loading, but it was approximately the same in jute nonwoven loaded composites.

The comparative analysis of specific mechanical properties of all the different types of composites reveals that the specific tensile strength and specific flexural strength of composite specimen WbH were highest among all the developed composites. The specific impact strength

of hybrid composite loaded with 7.64wt% of UD glass was the highest among all the composites. It has also been found that the equilibrium water content of cotton web reinforced composite was highest and polyester web reinforced composites was lowest.